Why Does Spousal Education Matter for Earnings? Assortative Mating or Cross-productivity*

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Abstract

In interpreting the positive relationship between spousal education and one's earnings, economists have two major hypotheses: cross-productivity between couples and assortative mating. However, no prior empirical study has been able to separate the two effects. This paper empirically disentangles the two effects by using twins data that we collected from urban China. We have two major innovations: we use twins data to control for the unobserved mating effect in our estimations, and we estimate both current and wedding-time earnings equations. Arguably, the cross-productivity effect takes time to be realized and thus is relatively unimportant at the time of the wedding. Any effect of spousal education on wedding-time earnings should more likely be the mating effect. We find that both cross-productivity and mating are important in explaining the current earnings. Although the mating effect exists for both husbands and wives, the cross-productivity effect only runs from Chinese husbands to wives. We further show that the cross-productivity effect is realized by increasing the hourly wage rate rather than working hours.

JEL Classification: J31, O15, P20

1 Introduction

Economists have long noticed the positive relationship between spousal education and one's earnings (Benham, 1974). Two major hypotheses have been put forward to interpret this positive correlation. First, the cross-productivity hypothesis, which maintains that spousal education helps an individual to accumulate human capital and increase earnings: for example, couples can share ideas within the family and this is considered productive (see, e.g., Benham, 1974; Scully, 1979; Kenny, 1983; Wong, 1986). Second, the observed correlation may simply be a consequence of assortative mating in the marriage market: that is, those who marry well-educated people are of high ability (Welch, 1974; Liu and Zhang, 1999). According to the Becker (1973 and 1974) model, both hypotheses can in theory be correct.

Despite this debate, few empirical studies have explicitly demonstrated the existence of either cross-productivity or the mating effect. In econometric language, the cross-productivity effect is the causal effect of spousal education on earnings, but the mating effect is caused by omitted variables. An ordinary least squares (OLS) estimate of the effect of spousal education on earnings cannot show the causal effect, because spousal education may have picked up one's own ability or the mating effect (Boulier and Rosenzweig, 1984).

We will attempt to empirically distinguish between cross-productivity and the mating effect by employing unique twins data that we recently collected from urban China. There are two major innovations in our designs of the tests and data collection. Our first innovation is the use of twins data to control for the omitted variable bias, or the mating effect in our estimations. As monozygotic (from the same egg) twins possess identical genes and similar family background, their unobservable abilities and family backgrounds are also very similar. Hence, taking the within-twins difference would largely remove the bias caused by the assortative mating effect with respect to one's unobservable ability or family background.

However, within-twins estimations may not completely remove all omitted abilities (or the mating effect), because abilities may not be fully explained by gene and family background. Our second innovation is to deal with this issue. In our survey, we collected information on one's earnings and other variables at the time of marriage and we can estimate a wedding-time earnings equation. By comparing the estimated effects on current earnings and the wedding-time earnings, we can distinguish the cross-productivity effect from the mating effect. Because the cross-productivity effect takes time to be realized, it is relatively unimportant at the time of the wedding. Any effect of spousal education on the wedding-time earnings would more likely be the mating effect.

Our empirical work shows that ordinary least squares estimates do not bias the effect of spousal education on one's earnings. The simple OLS estimate using the twins sample shows that the overall marginal benefit of spousal education on current earnings is 7 percent. This effect is halved (about 3.5 percent) when we control for one's own schooling and work experience. When we apply the within-twins fixed-effect model, the effect is very similar (3.6 percent), which suggests that there may indeed be a cross-productivity effect and that the gene or family background does not bias the estimation of the cross-productivity effect. To further disentangle the cross-productivity effect from the mating effect, we estimate the wedding-time earnings equation. As the cross-productivity effect is relatively unimportant at the time of the wedding, this estimate establishes an upper bound for the remaining mating effect that cannot be controlled for by the within-twins estimations. Our within-twins estimations show that the upper bound for the remaining mating effect is zero, which means that the whole mating effect can be well controlled for by the within-twins estimations. Because within-twins estimations can fully control for the mating effect, the significant effect of spousal education on current earnings must be the cross-productivity effect, which is 3.6

percent per year of spousal schooling in our sample.

The fact that the gender difference often appears within marriage motivates us to estimate the earnings equations by gender. There is indeed a gender difference in terms of the return to spousal education. For males, we find that the positive effect of the wife's education on both current earnings and wedding-time earnings disappears when we use within-twins estimations, which suggests that the effect of the wife's education on the husband's earnings is purely a result of mating (or gene or omitted family background). In contrast, although the husband's education has no effect on his wife's wedding-time earnings, it has a positive effect on his wife's current earnings (3.8 percent) even after we remove the bias caused by unobservable ability or family background. These findings suggest that there is a cross-productivity effect running from Chinese husbands to wives.

Spousal education may increase earnings by either changing the work hours or by raising the hourly wage. To differentiate between the two mechanisms, we perform the same analysis using the current working hours and the hourly wage rate as dependent variables. The hourly wage rate is calculated by dividing the monthly earnings by total hours worked in a month. The results using hourly wage rate are similar to those using monthly earnings. Mating is important for both sexes, but only the husband's education has a cross-productivity effect on the wife's hourly wage rate. We also find that the wife's education tends to increase the husband's working time.

Our finding that spousal education has a cross-productivity effect can shed light on our understanding of the theories of human capital, marriage and family. Recently, there have been advances in the empirical literature of human capital, which uses novel methods to control for unobservables and to measure the causal effect of human capital on earnings and on its intergenerational transfer. However, this literature has been focused on either one's own human capital (see e.g., Ashenfelter and Krueger (1994) and Ashenfelter and Rouse (1998)) or parental human capital (see e.g., Behrman and Rosenzweig (1999) and Plug (2004)). As far as we know, few have attempted to measure the causal effect of spousal education on earnings. Our finding suggests that marriage may improve one's human capital through learning within-marriage, which is true for Chinese wives. One can accumulate human capital not only from formal education or from having well-educated parents, but also from marrying a well-educated spouse.

This paper is organized as follows. Section 2 introduces the methods of estimations that draw on twins data. Section 3 describes the survey and data. Sections 4, 5, and 6 report the empirical results. Section 7 concludes the paper.

2 Empirical Strategies

Our empirical work will begin with estimating the log current earnings equation given as

$$y_i^c = X_i\alpha + \beta sedu_i + Z_i\gamma + \mu_i + \epsilon_i, \tag{1}$$

where the subscript i refers to individual i, and y_i^c is the logarithm of current earnings. $sedu_i$ is individual $i's$ spousal education. X_i is the set of observed family variables. Z_i is a set of observed individual variables that affect earnings, which include one's own education, age, age squared, gender, and job tenure. μ_i represents unobservable variables that also affect earnings: that is, the effect of ability or family background. ϵ_i is the disturbance term, which is assumed to be independent of Z_i and μ_i.

The ordinary least squares (OLS) estimate of β in equation (1) might be regarded as the cross-productivity effect, if we can control for the assortative mating effect by Z_i and μ_i. Such an estimate of the cross-productivity effect β is generally biased because we normally cannot perfectly measure μ_i, which may be correlated to $sedu_i$. This bias can also be called the assortative mating in education: that is, matching one's ability or family background with spousal education so that more able people are both likely to get higher earnings and tend to marry better educated partners; without controlling μ_i, β is still a combination of both the cross-productivity effect and the assortative mating effect where the latter is the bias to the estimate of the pure cross-productivity effect.

One approach to control for the mating effect is to apply the fixed-effects model to twins samples. As monozygotic twins are genetically identical and have the same family backgrounds, they should have the same μ_i. Taking the within-twins difference will eliminate the ability and family effect μ_i and will separate the unobserved mating effect from the causal cross-productivity effect. Intuitively, by contrasting the earnings of identical twins with different spousal education, we could ensure that the correlation we observe between spousal education and one's earnings is not due to a correlation between spousal education and one's gene or family background.

The fixed effects (FE) model can be specified as follows. The current earnings equations of a pair of twins are given as,

$$y_{1i}^c = X_i\alpha + \beta sedu_{1i} + Z_{1i}\gamma + \mu_i + \epsilon_{1i} \tag{2}$$

$$y_{2i}^c = X_i\alpha + \beta sedu_{2i} + Z_{2i}\gamma + \mu_i + \epsilon_{2i} \tag{3}$$

where y_{ji}^c $(j = 1, 2)$ is the logarithm of the current earnings of the first and second twins in the pair. X_i is the set of observed variables that vary by family but not between the twins: that is, the family background variables. $sedu_{ji}$ $(j = 1, 2)$ is the spousal education for twin j in family i. Z_{ji} $(j = 1, 2)$ is a set of variables that vary between the twins.

A within-twins or fixed effects estimator of β for identical twins, β_{FE}, is based on the first-difference of equations (2) and (3):

$$y_{1i}^c - y_{2i}^c = \beta(sedu_{1i} - sedu_{2i}) + (Z_{1i} - Z_{2i})\gamma + (\epsilon_{1i} - \epsilon_{2i}) \tag{4}$$

The first difference removes both the observable and unobservable family effects: that is, X_i and μ_i. As μ_i has been removed, we can apply the OLS method to Equation (4) without worrying about bias that is caused by the omitted gene and family background variables.

3 Data

The data that we use are derived from the Chinese Twins Survey (CTS), which was carried out by the Urban Survey Unit (USU) of the National Bureau of Statistics (NBS) in June and July 2002 in five cities of China. The survey was funded by the Research Grants Council of Hong Kong. Based on existing twins questionnaires in the United States and elsewhere, the survey covered a wide range of socio-economic information. The questionnaire was designed by the two authors of this paper in close consultation with Mark Rosenzweig and Chinese experts from the NBS. Adult twins aged between 18 and 65 years were identified by the local Statistical Bureaus through various channels, including colleagues, friends, relatives, newspaper advertisements, neighborhood notices, neighborhood management committees, and household records from the local public security bureau. Overall, these channels permitted a roughly equal probability of contacting all of the twins in these cities; hence the twins sample that was obtained is approximately representative. (The within-twins estimation method that is used for this study controls for the first-order effects of any unobserved characteristics that may have led to the selection of twins pairs in the sample). Questionnaires were completed through household face to face personal interviews. The survey was conducted with considerable care, and several site checks were made by Junsen Zhang and experts from the National Bureau of Statistics. Following appropriate discussion with Mark Rosenzweig and other experts, the data input process was closely supervised and monitored by Junsen Zhang himself in July and August 2002.

This is the first socio-economic twins data set in China, and possibly the first in Asia. The data set includes rich household socio-economic information for respondents in five cities: Chengdu, Chongqing, Haerbin, Hefei, and Wuhan. Altogether, there are 4,683 observations, in which 3,012 observations are from twins households. For the sample of twins, we can determine whether they are identical (MZ) or non-identical twins. We consider a pair of twins identical if both twins responded that they have identical hair color, look, and gender. Of these 3,012 individuals, we have complete information for 435 pairs of married twins (870 individuals), of which 226 pairs are identical twins (552 individuals).

There are a few unique survey designs for this study. First, we collected detailed information on the twins' spouses, in particular their years of schooling. Second, we collected information on current earnings (at the time of the survey, 2002) and the wedding-time earnings. Third, we collected information on current working hours, which allowed us to calculate the current hourly wage rate. We also tried to ask retrospective questions on the wedding-time working hours in our pretest, but found that most of them only remembered their monthly earnings and not the working hours. Thus, we only asked for the wedding-time monthly earnings and not for working time in the formal survey. As far as we know, our survey was the first to ask for this additional information, which will help us to disentangle the mating effect from the cross-productivity effect of spousal earnings. Finally, for comparison, non-twin households in the five cities were taken from regular households with whom the Urban Survey Unit conducts regular monthly surveys. The survey of non-twin households was conducted at the same time as the twin survey using a similar questionnaire. In total, we have 1573 non-twin individuals in the sample.

We define variables according to the literature. The descriptive statistics are reported in Table 1. In column 1, we report the mean of all variables for identical twins. Fifty-three percent of these identical twins were male. On average, they were 40 years old, had 12 years of schooling, and their spouses also had an average of 12 years of schooling. They had worked for 20 years, and had monthly earnings of 899 yuan in 2002, where earnings include wage, bonus and subsidies. They had also worked for 8 years and earned 342 yuan (normalized to 2002 yuan) when they got married. On average, they worked 174 hours a month in 2002, with an hourly wage rate of 5.6 yuan. The characteristics of the MZ twins sample are very similar to those of the sample of all twins (column 2) and the whole sample (column 3).

4 Empirical Results

In this section, we report the estimated effect of spousal education by using different samples and methods. We start with OLS regressions using the whole sample including twins and non-twins. These estimated coefficients are a way to check the representativeness of the MZ twins sample. We then report both OLS and within-twins fixed-effects estimates using the MZ twins sample.

In Table 2, we report the results of OLS regressions using the whole sample including both twins and non-twins. The dependent variable is the logarithm of monthly earnings. The t-statistics are calculated using robust standard errors allowing clustering at the family-level.

In column 1, we report a regression with spousal education, age, age squared, the male dummy, and years of marriage as independent variables. The regression shows that a person can get a 5.1 percent increase in earnings when the spousal education increases by one year. This effect is precisely estimated with a t-statistic of 4.57. The only other independent variable that is significant is the male dummy, with males having a 27 percent earnings premium.

In column 2, we add one's own education and job tenure as independent variables.

With these two new independent variables, the coefficient on spousal education drops to 2.8 percent, though it remains significant. This drop suggests that there is a mating effect, i.e., spousal education in column 1 has picked up the positive effect of one's own human capital variables. Indeed, one's own human capital variables, education and tenure, have a positive and significant effect on earnings. Increasing one's own education by one year increases earnings by 5.9 percent, while having one more year of tenure raises earnings by 1.5 percent.

Next, we repeat the same OLS regressions using the MZ twins sample. Comparing the OLS results of the whole sample with those of the MZ twins sample is a way to check the representativeness of our twins sample. As we only use MZ twins, the sample size is reduced to 552 (or 276 pairs of twins).

The regression results that are reported in columns 3-4 of Table 2 suggest that our MZ twins sample is somewhat representative in terms of the estimated coefficients. The effect of spousal education is about 7 percent with a t-statistic of 9.04 when we do not control one's own education and tenure. After controlling for one's own education and tenure, the effect of spousal education reduces to 3.5 percent but remains significant.

To summarize, the OLS estimates of the effects of spousal education are rather large even after we control for many covariates, including one's own education. The remaining effect is 3.5 percent in column 4 of Table 2, which is precisely estimated with a t-statistic of 3.87. However, the OLS model cannot identify how much of this estimate is due to the cross-productivity effect, and how much is due to mating, i.e., the effect of unobserved ability or family background. Next, we will try to distinguish between the two effects.

In columns 5-6 of Table 2, we report the results of within-twins fixed-effects estimations of the earnings equation, or the estimations of Equation (4). As MZ twins have the same age and gender, these two variables are dropped when taking the within-twins difference.

The within-twins estimates of the effect of the spousal education are very similar to the OLS estimates. Comparing column 6 to column 4, the coefficient for spousal education barely changes, though that for one's own education decreases dramatically in the within-twins estimate. These results imply that the mating effect has been well controlled for in the OLS specification in column 4, and the remaining positive effect of spousal education is very likely to be the true cross-productivity effect.

One interesting finding is that the effect of spousal education is greater than that of one's own education in the within-twins estimate in column 6 of Table 2, though the effect of spousal education is smaller in the OLS estimate (column 4). This happens because one's own education is more associated with one's own unobserved ability or family background than spousal education, and therefore becomes less important once we control for the unobserved gene and family background variables.

5 Potential Biases of Within-twins Estimates and Solutions

5.1 Potential Biases

Bound and Solon (1999) examined the implications of the endogenous determination of which twin receives more formal education, and concluded that twins-based estimation is vulnerable to the same sort of bias that affects conventional cross-sectional estimation. The resultant major concern of the within-twins estimate is whether it is less biased than the OLS estimate, and therefore a better estimate (Bound and Solon, 1999; Neumark, 1999). From this work we can argue that although the within-twins differencing removes genetic variation, i.e., it removes μ_i from Equation (4), this difference may still reflect an ability bias because ability is more than just genes. In other words, within-twins estimation may not completely eliminate the bias of conventional cross-sectional estimation, because the within-twins difference in ability may remain in $\epsilon_{1i} - \epsilon_{2i}$ in Equation (4), which may be correlated with $sedu_{1i} - sedu_{2i}$. If endogenous variation in spousal education comprises as large a proportion of the remaining within-twins variation as it does of the cross-sectional variation, then within-twins estimation is subject to as large an endogeneity bias as cross-sectional estimation.

Although within-twins estimation cannot completely eliminate the bias of the OLS estimator, it can tighten the upper bound on the return to spousal education. Ashenfelter and Rouse (1998), Bound and Solon (1999), and Neumark (1999) debated the bias with OLS and within-twins estimation at length. Note that the bias in the OLS estimator depends on the fraction of variance in spousal education that is accounted for by variance in unobserved ability that may also affect earnings: that is, $\frac{cov(sedu_i,\mu_i+\epsilon_i)}{var(sedu_i)}$. Similarly, the bias of the fixed effects estimator depends on the fraction of within-twins variance in spousal education that is accounted for by within-twins variance in unobserved ability that also affects earnings, that is, $\frac{cov(\Delta sedu_i,\Delta\mu_i+\Delta\epsilon_i)}{var(\Delta sedu_i)}$. If we are confident that spousal education and the earnings error term are positively correlated both in the cross-sectional and within-twins regressions, and if the endogenous variation within a family is smaller than the endogenous variation between families, then the fixed effects estimator is less biased than the OLS estimator. Hence, even if there is an ability bias in the within-twins regressions, the fixed effects estimator can still be regarded as an upper bound on the return to spousal education (if spousal education and ability are positively correlated); in which case, we can credit the within-twins estimates with having tightened the upper bound on the return to spousal education.

To examine whether the within-twins estimate is less biased than the OLS estimate, we follow Ashenfelter and Rouse (1998) and conduct a correlation analysis. We use the correlations of average family spousal education over each twin pair with the average family characteristics that may be correlated with ability (for example, own education, membership of the Chinese Communist Party, working in a foreign firm, and job tenure) to indicate the expected ability bias in a cross-sectional OLS regression. We then use the correlations of the within-twins differences in spousal education with the within-twins differences in these characteristics to indicate the expected ability bias in a within-twins regression. If the correlations in the cross-sectional case are larger than those in the within-twins case, then the ability bias in the cross-sectional regressions is likely to be larger than the bias in the within-twins regressions.

The correlation tests that are reported in Table 3 suggest that the within-twins estimation of the return to spousal education may be less affected by omitted variables than the OLS estimation. Note that the correlation between average family spousal education and average education is as large as 0.54 (column 1, row 1), which suggests that twins in families with a high average level of education marry highly educated people. However, the correlation of the within-twins difference in spousal education and the within-twins difference in education is only 0.15. This suggests that, using education as a measure of ability, the within-twins difference in spousal education is less affected by ability bias than the average family spousal education. However, this within-twins correlation is still statistically significant and large in magnitude, which suggests that within-twins differencing cannot completely eliminate the ability bias or the mating effect that is embodied in spousal education. Thus, the within-twins estimation may only establish an upper bound for the estimated return to spousal education. The evidence is suggestive even though these characteristics are an incomplete set of ability measures.

5.2 Remaining Mating Effect in Within-twins Estimates

The last subsection shows that we are concerned that the within-twins estimations may not completely remove all the mating effects, and that the estimated coefficient on spousal education on current earnings may still consist of both the cross-productivity effect and the remaining mating effect. Generally, it is very difficult to completely disentangle the two effects empirically.

Another innovation of our paper is to establish an upper bound for the omitted mating effect by estimating the wedding-time earnings equation. As couples have fewer opportunities to help each other accumulate their human capitals before the wedding, the cross-productivity effect should be relatively unimportant at this time. The within-twins estimate of the effect of spousal education on the wedding-time earnings can therefore establish an upper bound for the omitted mating effect in such a model. The specific wedding-time earnings equations of a pair of twins are given as,

$$y_{1i}^m = X_i\alpha^m + \beta^m sedu_{1i} + Z_{1i}\gamma^m + \mu_i + \upsilon_{1i} \tag{5}$$

$$y_{2i}^m = X_i\alpha^m + \beta^m sedu_{2i} + Z_{2i}\gamma^m + \mu_i + \upsilon_{2i} \tag{6}$$

where y_{ji}^m $(j = 1,\ 2)$ is the logarithm of the wedding-time earnings of the first and second twin in the pair. A within-twins estimator for identical twins is based on the first difference of equations (5) and (6):

$$y_{1i}^m - y_{2i}^m = \beta^m(sedu_{1i} - sedu_{2i}) + (Z_{1i} - Z_{2i})\gamma^m + (\upsilon_{1i} - \upsilon_{2i}) \tag{7}$$

The within-twins estimate of β^m will consist of both the cross-productivity and the remaining mating effect, if mating is individual-specific (rather than family specific). However, as cross-productivity is relatively unimportant at the time of the wedding, the estimated β^m establishes an upper bound for the remaining mating effect that is not controlled for by the within-twins estimations. If our within-twins model can fully control for the mating effect, then the estimated β^m should be close to zero.

The estimation results of the wedding-time earnings equation suggest that our econometric specification can control for the whole mating effect. In Table 4, we report the estimates of the wedding-time earnings equation. Note that spousal education has a large and significant coefficient in OLS regressions in column 1 of Table 4; however, it becomes much smaller and insignificant once we also include one's own education and tenure as covariates in column 2. Similar to the OLS estimate, the within-twins estimate in column 4 is also smaller in magnitude and insignificant. The fact that spousal education has no effect on the wedding-time earnings suggests that the whole mating effect can be well controlled for by either observable human capital variables or by taking the within-twins difference.

The results for the current and wedding-time earnings equations can be used to infer whether there is a cross-productivity effect. The estimate of the wedding-time earnings equation suggests that the mating effect can be well controlled for by our within-twins model. If we assume that the mating effect of spousal education in the current earnings equation can be fully controlled for, just as it can be in the wedding-time earnings equation, then the significant coefficient for spousal education in the current earnings equation means that there is a positive cross-productivity effect. As has been shown by column 6 of Table 2, the cross-productivity effect of spousal education is 3.6 percent per year of spousal schooling.

6 Further Analysis

6.1 Difference between Sexes

Our analysis pooled males and females together. However, there are reasons to believe that the role of cross-productivity is different for husbands and wives within a family. The two sexes may have different learning abilities and more importantly, one may be more dominant.[1] For example, if the husband dominates in a family and makes job and other activity related decisions for the wife, then one would expect the husband's education to be important in determining the wife's earnings, but the wife's education to be unimportant in determining the husband's earnings.

In fact, China provides an interesting social setting where one might expect that males dominate in families. Although in the West patriarchalism has become antiquated, Chinese families remained patriarchal until quite recently (Ch'u, 1961; Hamilton, 1990) when the father was still the head of the family and had authority over all of its members. His control of the family economy and his power to make decisions on resource allocation strengthened that authority. The concept of ancestor worship, central to the solidarity of the family and to its perpetuation, further enhanced the authority of the family head, who was also the family priest. In recent years, however, women have been gaining greater decision-making power in daily family affairs. According to a national survey on family life conducted by the All-China Women's Federation (China Daily, September 10, 2002), 57 percent of wives have more say than their husbands in decisions on minor, daily spending, whereas only 13.9 percent of husbands assume the role of decision-maker in similar matters.[2] However, when it comes to major family decision-making, husbands still have the upper hand, with 24.5 percent having the final say; whereas only 7 percent of wives make similar decisions. These survey results indicate that although the women's position in the family has improved, men still dominate in Chinese families.

The results of regressions using the male and female twins sample separately show a difference between sexes. In the left panel of Table 5, we report the results of within-twins fixed-effects estimations of the spousal education on male's current and wedding-time earn-

[1] In a sense, when one sex dominates, it is like the family in Becker's unitary model (Becker, 1991).
[2] The remaining spouses make such decisions jointly.

ings, or the estimations of Equations (4) and (7) for males. For males, our within-twins estimates show that the wife's education has no effect on either his current or wedding-time earnings (columns 1-4), which suggests that no cross-productivity effect from wives to husbands can be identifiable for Chinese families. The within-twins pair results for the female twins sample are quite different (columns 5-8). Although the husband's education has a significant positive effect on his wife's current earnings, it has zero effect on his wife's wedding-time earnings. These results together suggest that there is indeed a cross-productivity effect from Chinese husbands to their wives.

6.2 Longer Hours or Better Paid?

In the above analysis, we use monthly earnings as our dependent variable. Spousal education may have an effect on monthly earnings through either hourly wage rate or monthly working hours. To differentiate between the two channels, we examine the effects of spousal education on one's current hourly wage and working hours. As the effect for the male and female samples are different, we conduct the analysis for male and female MZ twins samples separately.

The regression results again show that the wife's education has no effect on the hourly wage rate of her husband, while the husband's education has a positive effect on the hourly wage rate of his wife. In column 1 of Table 6, the OLS estimations show that spousal education has a significant effect on his hourly wage. However, the effect becomes zero after we control for his ability or family background by the within-twins estimations in column 2. These empirical results suggest that, consistent with those in Table 5, the wife's education has no cross-productivity effect on the husband's hourly wage. In contrast, the husband's education has a cross-productivity effect on the hourly wage rate of his wife, as shown by the within-twins estimate in column 6.

It is also interesting to see how one's own and spousal education affect working hours. Column 3 shows that the husband's own education has a significant negative effect on his current working hours, while the wife's education has a significant positive effect on his working hours. After we employ within-twins model in column 4, the effect of the husband's own education becomes zero. Because a man's own education is positively correlated to his ability, the change of the effects demonstrates that more able men spend less time working and a man's education has no effect on his own working hours. Interestingly, the within-twins estimate of the effect of the spousal education on a man's working hours more than doubles that of OLS estimate, which suggests that the wife's education has a positive effect on the husband's working hours. One potential explanation is that women with higher education can take better care of the family and the husband can spend more time working. Columns 7 and 8 show that both a woman's own education and spousal education have no effects on her working hours.

To summarize, we obtain similar results when we use the hourly wage rate as the dependent variable: the mating effect is important for both males and females, but the cross-productivity effect in terms of wage only exists from husbands to wives. There is additional evidence that men with better-educated wives tend to work longer.

7 Conclusion

We empirically distinguish between the cross-productivity and mating effect by employing unique twins data we recently collected from urban China. By using the within-twins model to control for the omitted variable bias, we can largely remove the bias caused by the assortative mating effect with respect to one's unobservable ability or family background. By comparing the estimated effects on current earnings and the wedding-time earnings, we can establish an upper bound for the omitted mating effect.

We find that our within-twins model can well control for the mating effect, and any effect of spousal education on current earnings is the cross-productivity effect. The cross-productivity effect in our sample is 3.6 percent. Our further analysis shows that the cross-productivity effect only happens from husbands to wives but not vise versa, which reflects male-dominance in Chinese society. Finally, by estimating both the hourly wage and monthly working hours equations, we find that the cross-productivity effect of husbands on wives is through increasing the hourly wage of wives.

The finding that spousal education has a cross-productivity effect could shed light on our understanding of the theories of human capital, marriage, and the family. Previous empirical works have shown that people can acquire earnings-enhancing human capital through formal schooling and intergenerational transfer, but have generally paid less attention to the further improvement of human capital after the formal education. In this paper, we find at least one potential channel of the post-school improvement of human capital, that is, learning within marriage. This has two implications. First, a rise in education not only improves one's own earnings and household production, but also raises the earnings of the spouse. If we only considered the effect on own earnings, we would have missed an important part of the total effect of one's education on family earnings. Second, it seems that learning beyond normal schooling ages may have good payoffs both within and outside families. This implication becomes even more important in the light of the continuing rise of life expectancy.

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Table 1: Descriptive Statistics of the Twins and Non-Twins Samples

Variable	MZ Twins (1)	All Twins (2)	Whole Sample (3)
Gender (male=1, female=0)	0.53	0.52	0.51
	(0.50)	(0.50)	(0.50)
Age	39.95	38.83	40.79
	(7.82)	(7.72)	(8.25)
Own education (years of schooling)	11.88	11.78	11.65
	(3.08)	(3.05)	(3.02)
Tenure (number of years	20.24	19.13	20.65
working full time since age 16)	(8.51)	(8.29)	(8.76)
Current earnings (monthly wage,	898.70	892.21	872.76
bonus and subsidy in 2002 yuan)	(520.60)	(568.27)	(593.16)
Current hourly wage rate	5.63	5.64	5.58
	(3.73)	(3.87)	(4.66)
Current monthly work hours	173.62	175.49	173.01
	(39.79)	(44.25)	(43.10)
Wedding-time tenure	7.51	7.40	7.51
	(4.69)	(4.46)	(4.49)
Wedding-time earnings (monthly wage,	342.48	355.02	289.90
bonus and subsidy in 2002 yuan)	(342.28)	(339.07)	(428.01)
Spousal education (years of schooling)	11.55	11.62	11.46
	(3.11)	(3.09)	(3.28)
Sample size	552	870	2443

Table 2: OLS and Within-Twin-Pair Estimates of the Effect of Spousal Education on Current Earnings

Dependent Variable	log(current earnings)					
Sample	Whole Sample		MZ Twins Sample		MZ Twins Sample	
Model	OLS		OLS		Within-twin-pair	
	(1)	(2)	(3)	(4)	(5)	(6)
Spousal education	0.051***	0.028***	0.070***	0.035***	0.039***	0.036***
	(4.57)	(3.45)	(9.04)	(3.87)	(3.39)	(3.06)
Own human capital attributes						
Education		0.059***		0.068***		0.024
		(11.88)		(8.60)		(1.35)
Age	-0.007	-0.016	0.048*	0.042		
	(0.51)	(1.19)	(1.75)	(1.43)		
$Age^2/100$	0.015	0.009	-0.045	-0.045		
	(0.93)	(0.59)	(1.34)	(1.34)		
Male	0.269***	0.259***	0.308***	0.293***		
	(9.66)	(10.37)	(6.22)	(6.34)		
Job tenure		0.015***		0.007		0.008
		(4.74)		(0.97)		(0.66)
Years of marriage	-0.002	0.000	-0.006	-0.003	-0.008	-0.007
	(0.47)	(0.00)	(0.92)	(0.43)	(0.93)	(0.74)
Constant	5.985***	5.701***	4.702***	4.380***	6.309***	5.881***
	(18.80)	(20.42)	(8.38)	(7.43)	(35.24)	(15.73)
Observations	2462	2455	552	552	552	552
Twin pairs					276	276
R-squared	0.12	0.20	0.18	0.27	0.04	0.05

Robust t statistics in parentheses; OLS regressions allow clustering at the family level; All regressions include city dummies; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 3: Between-Families and Within-Twin-Pair Correlations of Education with Other Variables (276 twin pairs)

Between-family correlations		Within-twin-pair correlations	
	Spousal education		Δ Spousal education
Own education	0.5387*** (<0.01)	Δ Own education	0.1535*** (<0.01)
Own job tenure	-0.1722*** (<0.01)	Δ Own job tenure	0.0790*** (0.06)
Party membership	0.1470*** (<0.01)	Δ Party membership	-0.0015 (<0.97)
Working in foreign firm	0.0868** (0.05)	Δ Working in foreign firm	0.1500*** (<0.01)

Note: The significance levels are in parentheses. *significant at 10%; **significant at 5%; ***significant at 1%. The between-family correlations are the correlations between average family spousal education (average of the twins) and average family characteristics, and the within-twin-pair correlations are the correlations between the within-twin-pair differences in spousal education and the within-twin-pair differences in other characteristics.

Table 4: OLS and Within-Twin-Pair Estimates of the Effect of Spousal Education on the Wedding-time Earnings Using MZ Twins Sample

Dependent Variable	log(wedding-time earnings)			
Model	OLS		Fixed-Effect	
	(1)	(2)	(3)	(4)
Spousal education	0.053***	0.005	0.027	0.027
	(3.75)	(0.39)	(1.47)	(1.42)
Own human capital attributes				
Education		0.057***		0.011
		(3.83)		(0.38)
Male	0.103	0.135*		
	(1.35)	(1.88)		
Job tenure		-0.039***	0.103***	-0.010
		(6.23)	(7.42)	(0.53)
Years of marriage				
Constant	4.889***	5.449***	5.133***	5.218***
	(22.62)	(18.16)	(23.99)	(9.27)
Observations	552	552	552	552
Twin pairs			276	276
R-squared	0.06	0.20	0.01	0.01

Robust t statistics in parentheses; OLS regressions allow clustering at the family level; All regressions include city dummies; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 5: Within-Twin-Pair Estimates of the Effect of Spousal Education on Current and Wedding-time Earnings for Male and Female Twins

Sample	Male MZ Twins				Female MZ Twins			
Dependent Variable	log(current earnings)		log(wedding-time earnings)		log(current earnings)		log(wedding-time earnings)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Spousal education	0.027	0.025	0.039	0.046	0.046***	0.038**	0.019	0.016
	(1.41)	(1.29)	(1.08)	(1.25)	(3.18)	(2.55)	(1.23)	(1.03)
Own human capital attributes								
Education		0.008		-0.048		0.042*		0.082***
		(0.34)		(1.05)		(1.68)		(3.17)
Job tenure		-0.012		0		0.027		-0.021
		(0.70)		(0.00)		(1.56)		(1.15)
Years of marriage	-0.015	-0.014			-0.002	-0.001		
	(1.22)	(1.13)			(0.13)	(0.06)		
Constant	6.663***	6.837***	5.022***	5.502***	5.995***	5.052***	5.210***	4.632***
	(23.71)	(11.83)	(12.92)	(5.44)	(25.66)	(10.23)	(26.69)	(9.39)
Observations	294	294	294	294	258	258	258	258
Twin pairs	147	147	147	147	129	129	129	129
R-squared	0.03	0.03	0.01	0.02	0.07	0.11	0.01	0.10

Robust t statistics in parentheses; All regressions control city dummy variables; * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 6: OLS and Within-Twin-Pair Estimates of the Effect of Spousal Education on Current Hourly Wage Rate and Monthly Work Hours for Male and Female Twins

Dependent Variable	log(male hourly wage rate)		log(male work hour)		log(female hourly wage rate)		log(female work hour)	
Model	OLS	Within-twin pair	OLS	Within-twin pair	OLS	Within-twin pair	OLS	Within-twin pair
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Spousal education	0.045***	-0.007	1.844*	3.990**	0.015	0.032*	-1.099	-1.725
	(4.04)	(0.34)	(1.67)	(2.16)	(0.86)	(1.88)	(1.11)	(1.15)
Own human capital attributes								
Education	0.060***	0.016	-2.417**	-0.399	0.082***	0.025	0.061	1.541
	(5.66)	(0.62)	(2.17)	(0.17)	(5.73)	(0.87)	(0.07)	(0.62)
Age	-0.064		-2.346		0.129**		-1.473	
	(1.54)		(0.70)		(2.24)		(0.56)	
$Age^2/100$	0.064		6.098		-0.153**		2.531	
	(1.37)		(1.55)		(2.23)		(0.82)	
Job Tenure	0.016	0.012	-2.351*	-1.168	0.016	0.021	-1.433*	1.433
	(1.55)	(0.57)	(1.94)	(0.59)	(1.48)	(1.08)	(1.94)	(0.84)
Years of Marriage	0.007	0.011	-0.587	-0.644	-0.010	-0.004	0.896	0.627
	(0.68)	(0.80)	(0.75)	(0.54)	(1.10)	(0.27)	(1.23)	(0.50)
Constant	1.734**	1.142	219.569***	168.853***	-2.426**	0.420	211.612***	139.450***
	(2.00)	(1.65)	(3.28)	(2.72)	(2.13)	(0.76)	(3.96)	(2.89)
Observations	270	270	270	270	230	230	230	230
Twin pairs		135		135		115		115
R-squared	0.29	0.01	0.07	0.04	0.22	0.06	0.05	0.02

Robust t statistics in parentheses; OLS regressions allow clustering at the family level; All regressions include city dummies; * significant at 10%; ** significant at 5%; *** significant at 1%